

TORNADOES OF APRIL 2 AND 3, 1956

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ABSTRACT

A discussion of the synoptic situation leading to the occurrence of tornadoes on April 2 and 3 is presented. It is found that approximately the same instability and low-level moisture conditions existed on April 1, 2, and 3. Reasoning from the vorticity equation and upper-level charts suggests that a strong vertical motion field was the significant factor present on April 2 and 3, which was not present on April 1, a day without tornadoes.

1. INTRODUCTION

Tornadoes killing nearly 50 people, injuring hundreds, and causing damage in the millions cut a swath of destruction through a dozen Midwest States on April 2 and 3, 1956 (fig. 1A) in the largest family outbreak of tornadoes between January and May of 1956. Associated with a deep low pressure system moving eastward from Colorado, the first of these storms occurred in central Kansas shortly after 1800 CST, April 2. Over 20 tornadoes, numerous damaging wind storms, and hail were reported that night from southern Oklahoma, through central and eastern Kansas, extreme southwestern Missouri, and as far north as southwestern Iowa (fig. 1B). Five persons were killed in the tornado that moved through Drumright, Okla., about 2130 CST. In the afternoon and evening of the following day, tornadoes occurred again in a wide band extending north from Mississippi through western Tennessee (fig. 1C) and on both sides of Lake Michigan into central Wisconsin and western Michigan. The greatest loss of life in these storms was reported in Michigan where 17 persons were killed at Hudsonville and 6 persons died at Standale, a suburb of Grand Rapids. In all, over 60 tornadoes, not including several waterspouts on Lake Michigan, were reported on these two days.

The purpose of this paper is (1) to present the macro-scale synoptic features which appeared to be most important in producing the tornado activity; (2) to bring out some of the significant similarities and differences between synoptic conditions on April 1 and 2, 1956; and (3) to present certain mesoscale features detected by radar and sferics prior to and during tornado activity.

Several factors of particular interest were noted for the period of April 1-3, 1956. The first was the large amount of low-level moisture present over the area of Texas, Oklahoma, and Kansas as early as the morning of April 1, the day before tornado activity. Second was the great instability present (mostly as a result of moisture). Lifted indices [1] (a measure of stability based on average mois-

ture for the lower 3,000 feet and the prognostic surface temperature) were generally about -5 and the amount of lift required to release convective instability was small. The third was the prominent 500-mb. and jet patterns during April 2 and 3 over the central United States as compared with April 1. Last was the lack of clearly defined temperature and moisture tongues and wind patterns in the lower 10,000 feet, principally on April 2.

In the synoptic discussion as many concurrent data as practicable have been placed on one chart. Frontal positions, polar jet maxima, and low-latitude jet axes are superimposed on the 500-mb. charts, and the upper level jets are placed on the surface charts (taken from SELS Center analyses). Successive past positions of the surface Low, 500-mb. Low and trough, polar jet maximum, low-latitude jet axis, and the surface position of the dew point front at 0900 CST, April 2, are shown on a continuity chart (fig. 2). In the following discussion horizontal velocity divergence is called simply "divergence." Times on all charts are in Central Standard Time.

Synoptic material prior to 0900 CST, April 2 will be discussed first, followed by synoptic, radar, and sferics material from this time through the time of tornado occurrences in the eastern Kansas area on April 2. Last will follow the synoptic events for April 3. Since radar, sferics, and synoptic data were more sparse on April 3 than on April 2, the situation on April 3 will be treated in lesser detail.

2. SYNOPTIC SITUATION PRIOR TO 0900 CST, APRIL 2

Early on April 1 a strong upper-level short-wave trough was moving from southwestern United States toward the Central Plains into a region of abundant moisture and instability which extended from the Gulf of Mexico into Kansas. This short-wave trough and associated jet maximum appeared to be moving out of a deep elongated trough centered along the west coast. As the short wave moved eastward the relatively flat ridge over central United

become organized with the approach of the 500-mb. closed Low. At the surface, the 1530 cstr chart (fig. 3A) indicated for the first time two definite centers, both 990 mb., one remaining in southeastern Colorado and subsequently weakening and one forming near Garden City, Kans., near the juncture of the dew point front (western edge of strong moisture gradient) and the quasi-stationary front to the north. At the time of the formation of the Low in Kansas a squall line moved northeast at about 40 knots accompanied by large hail. About 1530 cstr, April 2 only two large precipitation cells were easily distinguishable by radar. One cell was followed by the 4-station sferics network of the Air Force. This cell, first detected at 1400 cstr, 20 nautical miles east-southeast of Wichita, Kans., was associated with hail, and was interpreted as being possibly tornadic. Later a sferics fix was associated with large hail 20 miles west-southwest of Emporia, Kans. The largest hail reported during the afternoon near sferics fixes was $1\frac{1}{4}$ inches at 1830 cstr, 5 miles north of Forbes Air Force Base, Topeka, Kans. No tornadoes were reported with these fixes.

By 1830 cstr (fig. 3B) the 990-mb. center near Garden City had moved eastward, to east of Dodge City. About this time another squall line was analyzed east of the dew point front extending from Abilene, Tex., into the low center at Dodge City. Also at 1830 cstr, radar indicated a line of moderate to strong echoes from 80 miles north-northwest of Grand Island, Nebr., through Russell, Kans., to a point 50 miles east of Gage, Okla. This was the squall line connected with the tornado activity that began about 1800 cstr. During the next 3 hours, the surface Low near Dodge City accelerated to the northeast (between 2130 cstr, April 2 and 0030 cstr, April 3 it deepened 3 mb.) as it was approached by the 500-mb. Low moving from the southwest (fig. 2). By 2035 cstr, April 2 (fig. 3C) the radar indicated that the squall line had lengthened rapidly to the north and south, extending from Huron, S. Dak., to 30 miles west of Lincoln, Nebr., to Hutchinson, Kans., then south-southeast to a point 30 miles east of Oklahoma City to 20 miles southeast of Mineral Wells, Tex. At 2100 cstr the radar indicated the squall line was dissipating in the vicinity of the surface Low in Kansas. At this time, the squall line divided into two segments. The southern segment, which was associated with most of the tornadoes, moved eastward at 40 knots. The northern segment of the line moved east-northeastward with decreasing intensity at a speed of 25 to 30 knots. A few reports of tornadoes were received in connection with the passage of this line in extreme northeastern Kansas and extreme southwestern Iowa. The organization and acceleration of a separate Low into an area of greater moisture and instability appeared to be the significant surface features associated with the tornado activity.

FEATURES IN THE LOWER LEVELS

East of the surface system after 0900 cstr, April 2, the lower levels were characterized by abundant moisture and

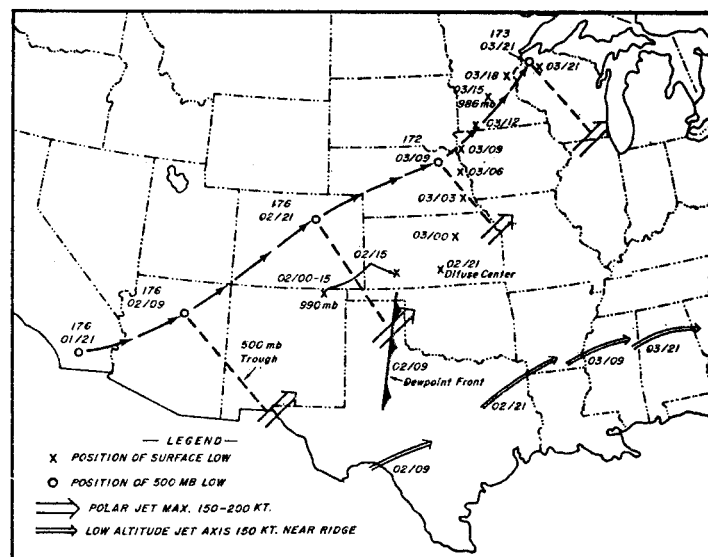


FIGURE 2.—Successive positions of surface Low, 500-mb. Low and trough, polar jet maximum, and low-latitude jet axis from 2100 cstr, April 1 through 2100 cstr, April 3, 1956. Also shown is the surface position of dewpoint front at 0900 cstr, April 2.

instability, weak thermal patterns, and strong but indefinite wind patterns. The average mixing ratio in the lower 3,000 feet was generally 11 to 13 gm./km. and lifted indices were -5 to -10 during the afternoon. Within the large warm sector it was difficult to determine the exact location of either thermal or moisture ridges at 850 mb. or the no-change line of apparent advection at 700 mb. An important feature was the strong east-west gradient of moisture and instability in western Oklahoma. Also, the changes in the low-level wind field appeared to be somewhat erratic (fig. 4). One feature observed was the increase of the gradient level wind (low-level jet) at 1500 cstr (fig. 4B) east of the dew point front. This occurred about the same time that the Low near Garden City formed. At the same time the jet in the lower levels showed little change ahead of the cold front extending into Colorado. This can be seen from the 850-mb. winds (fig. 5) which on April 2 were in most instances representative of the low-level jet. Thus, even though the low-level wind and temperature were undoubtedly important, the uncertainty in placement for this particular day made them difficult to interpret. The great instability and moisture were the most salient features in the low levels.

UPPER-LEVEL FEATURES

The features which appeared to be most important both in timing and in predicting the occurrence of tornadoes for April 2 were the short-wave trough and associated jet maximum which moved from the southwest into the Oklahoma-Kansas area (fig. 6). During this period, the jet maximum moved from near El Paso, Tex., at 0900 cstr, April 2, (fig. 6A), to near Childress, Tex. by 2100 cstr (fig. 6B). It appeared to move with the same speed

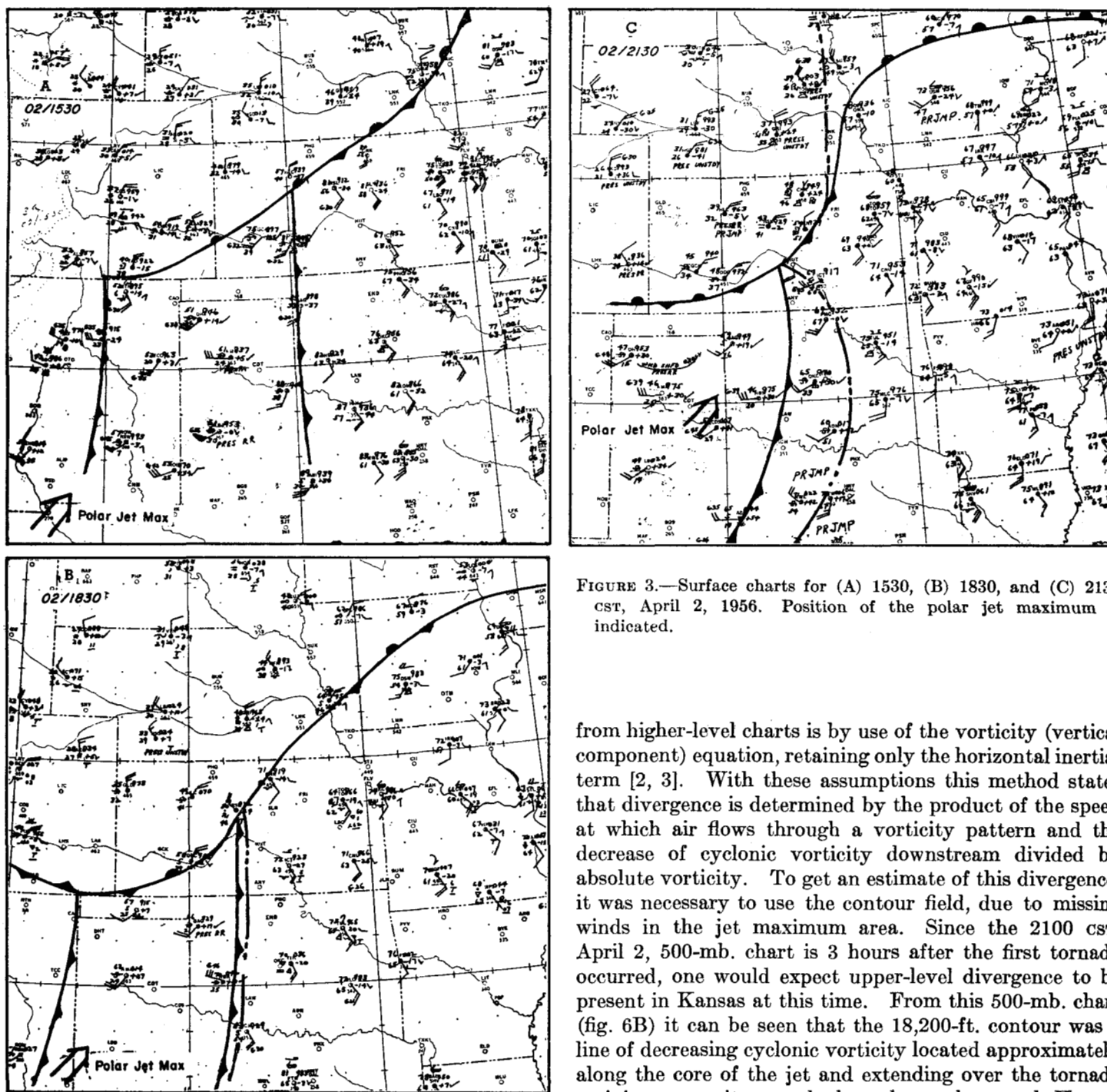


FIGURE 3.—Surface charts for (A) 1530, (B) 1830, and (C) 2130 CST, April 2, 1956. Position of the polar jet maximum is indicated.

as the 500-mb. center and remained to the southeast of the upper closed Low, moving northeastward at about 30 knots. The jet maximum was estimated to be 150 to 200 knots at an elevation near 25,000 feet at 2100 CST. Therefore, in Kansas and Oklahoma, events occurring near 500–400 mb. should have been representative of upper tropospheric conditions.

If a strong vertical motion field were moving into this area, it would be reasonable to expect divergence in the upper levels. One method of estimating this divergence

from higher-level charts is by use of the vorticity (vertical component) equation, retaining only the horizontal inertial term [2, 3]. With these assumptions this method states that divergence is determined by the product of the speed at which air flows through a vorticity pattern and the decrease of cyclonic vorticity downstream divided by absolute vorticity. To get an estimate of this divergence, it was necessary to use the contour field, due to missing winds in the jet maximum area. Since the 2100 CST, April 2, 500-mb. chart is 3 hours after the first tornado occurred, one would expect upper-level divergence to be present in Kansas at this time. From this 500-mb. chart (fig. 6B) it can be seen that the 18,200-ft. contour was a line of decreasing cyclonic vorticity located approximately along the core of the jet and extending over the tornado activity area; it passed through south-central Kansas near Wichita and north to Concordia. On the assumption that this contour approximated a streamline and that wind speed decreased linearly from 150 knots at Childress, Tex., to 70 knots at Salina, Kans., the distribution of divergence in units of 10^{-5} sec^{-1} shown along this contour on the 2100 CST, April 2, 500-mb. chart (fig. 6B) was obtained. By comparing this with a streamline for the same area on the 0900 CST, April 2, 500-mb. chart (fig. 6A), where the speed decreased from 65 knots at Childress to 35 knots at Salina and change in direction was only 10° , it was found that the average divergence between Childress and Salina increased from less than 1×10^{-5}

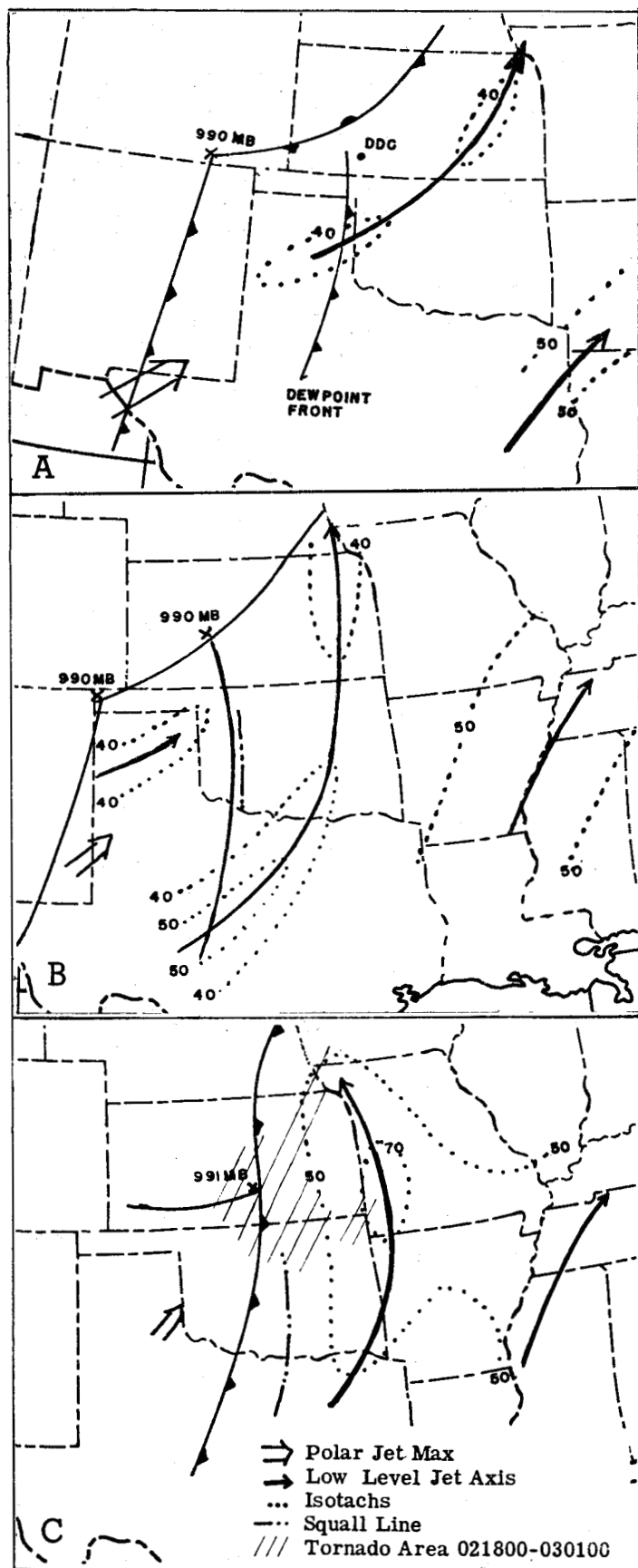


FIGURE 4.—Low-level wind field for (A) 0900, (B) 1500, and (C) 2100 CST, April 2, 1956.

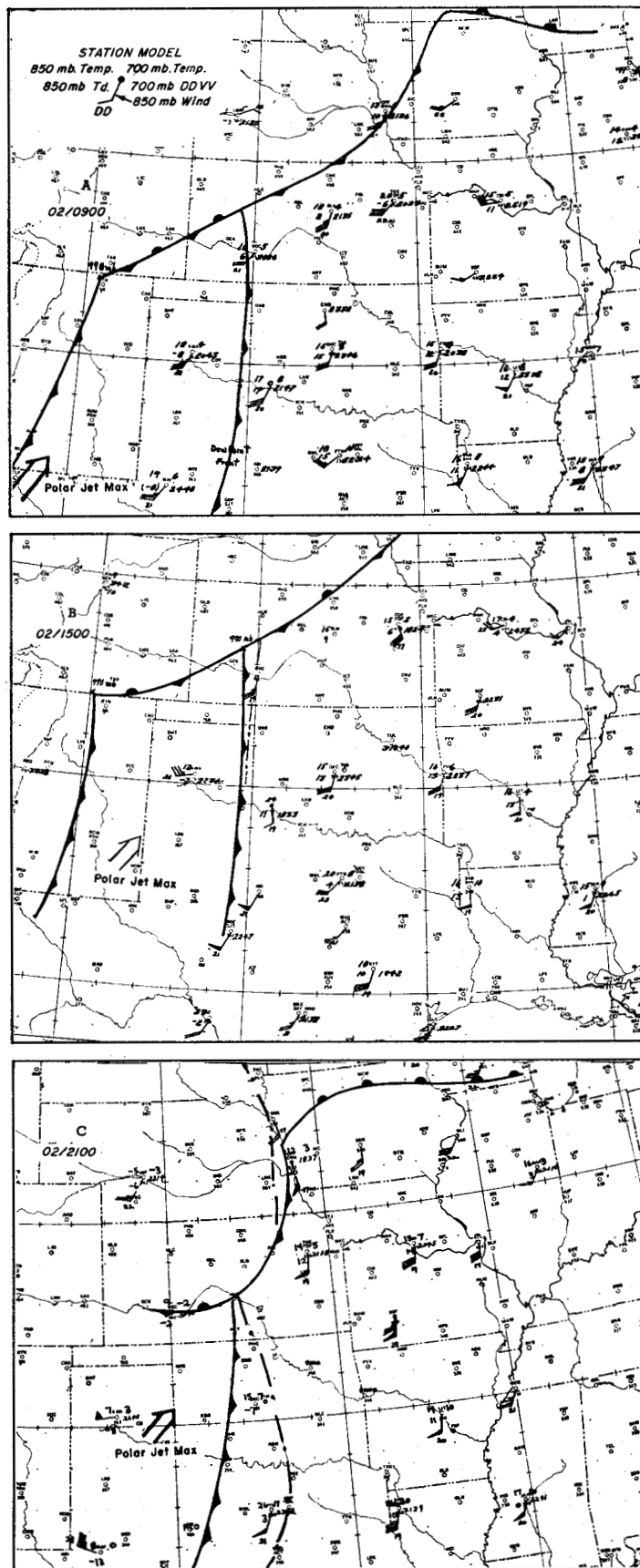


FIGURE 5.—850-mb. temperature, dewpoint, and wind and the 700-mb. temperature and wind, with the surface fronts and dewpoint front. (A) 0900, (B) 1500, and (C) 2100 CST, April 2, 1956.

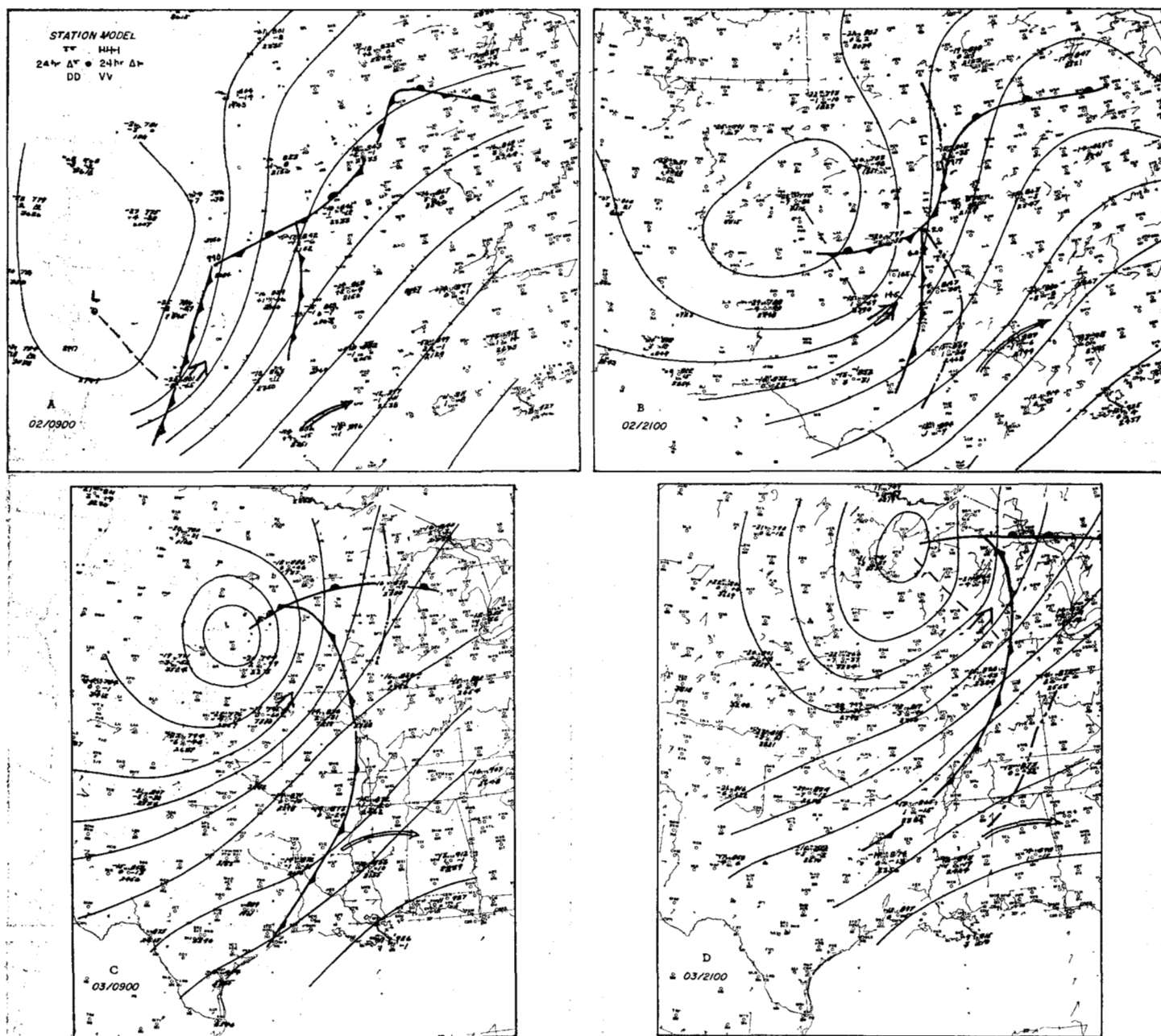


FIGURE 6.—500-mb. charts with surface fronts superimposed and the positions of the polar jet maximum and low-latitude jet axis indicated. (A) 0900 cstr, April 2; (B) 2100 cstr, April 2; (C) 0900 cstr, April 3; and (D) 2100 cstr, April 3. In (B) divergence values shown along the 18,200-ft. contour from Childress, Tex., to Salina, Kans., are in units of 10^{-5} sec^{-1} .

sec^{-1} to about $8 \times 10^{-5} \text{ sec}^{-1}$. Even though this computed change is only an approximation, it does give an indication of the increase of divergence (and thus vertical velocity) with time, as well as the gradient of the divergence field, which was moving into the area of sufficient moisture and instability. It appears, therefore, that the significant feature of the upper levels was the apparent increase of divergence with time over Kansas.

4. COMPARISON OF CONDITIONS ON APRIL 1 AND 2, 1956

It is interesting to compare the situation of April 1, which did not have tornadoes, with that of April 2, which had over 20 tornadoes. The significant difference between the two days was not the amount of low-level moisture or instability present, since on both days they were nearly the same. Lifted indices for the afternoon of April 1 were

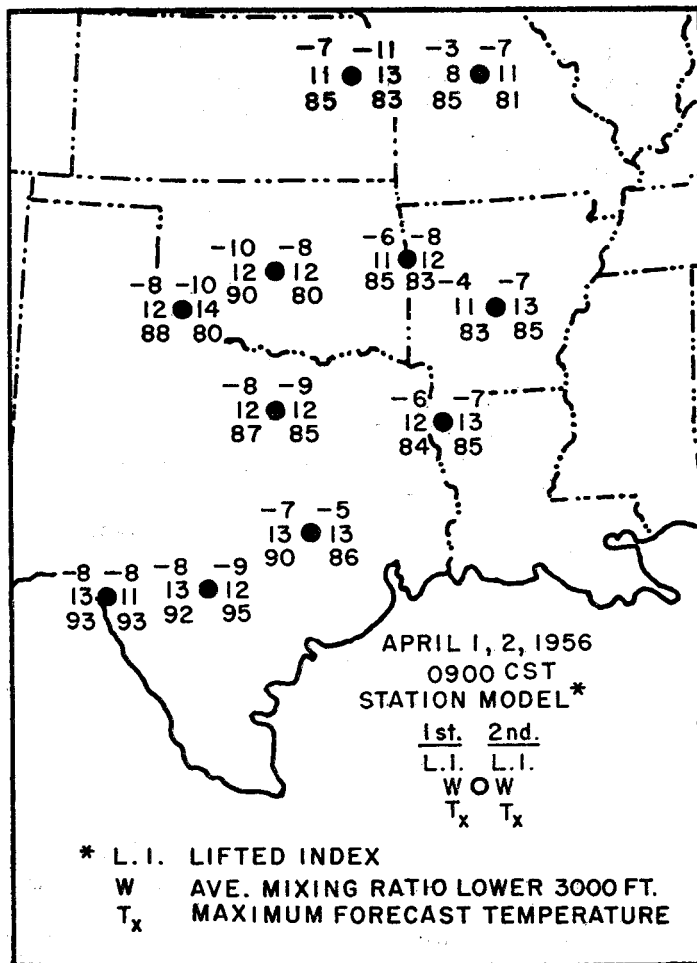


FIGURE 7.—Moisture and stability chart for 0900 cst, April 1 and 2, 1956.

only slightly more stable than on April 2 (fig. 7), and the average mixing ratio in the lower 3,000 feet was similar to that for the 2d over much of Kansas, Oklahoma, and Texas. Also, thunderstorms occurred in Oklahoma on April 1 indicating that convective activity was not suppressed by stability.

On April 1 there appeared to be neither a clearly defined surface front nor an upper-level trough present in the Kansas area. Associated with the trough which moved into the Kansas area on April 2 was an intensification of the dew point front into a cold front, probably in response to low-level convergence or by reinforcement by a front which remained indistinct until moving over the Rockies. The significant macroscale difference between the two days appears to have been the easily detectable upper-level trough and jet pattern with its associated vertical motion field which moved into an area of greater instability and moisture on April 2. This was the prominent feature which made April 2 a tornado day and April 1 only a thunderstorm day.

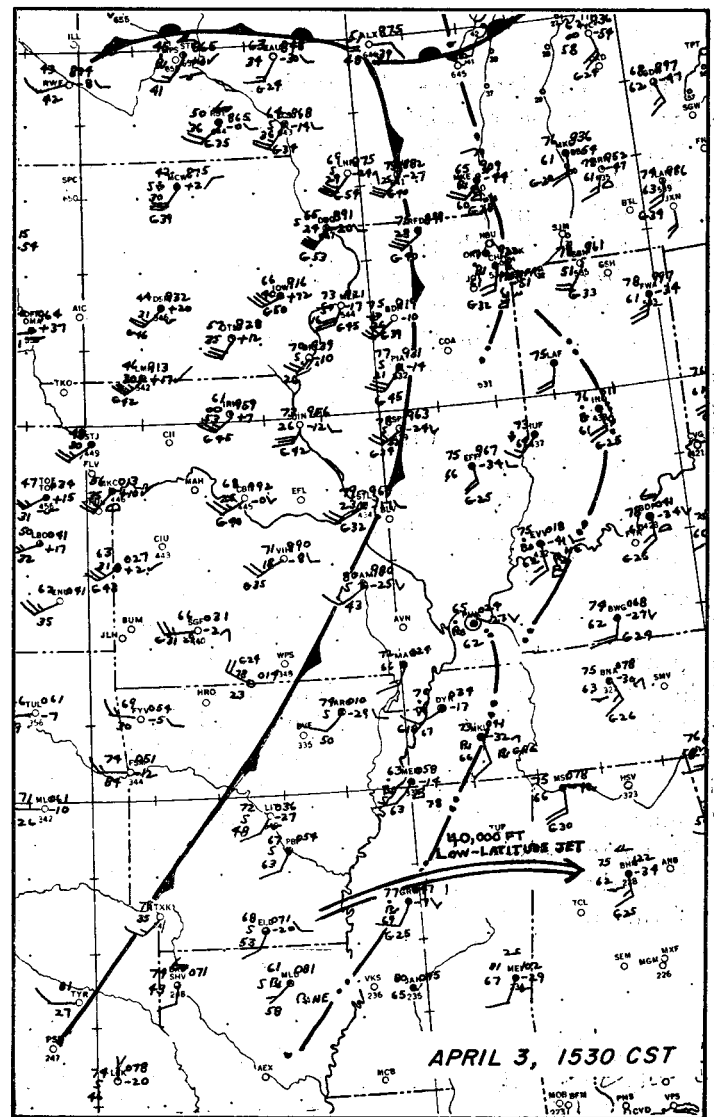


FIGURE 8.—Surface chart for 1530 cst, April 3, 1956.

5. EVENTS AFTER 0200 CST, APRIL 3

During the early morning of April 3, thunderstorms continued both in the cold air as well as in the warm sector. Convective activity continued on into the day, with several squall lines or areas occurring mostly with the surface Low to the north which had continued its north-east movement (fig. 2), becoming occluded before noon on April 3. At 1530 cst, April 3 (fig. 8), the surface Low was located near Saint Cloud, Minn. The feature at the surface which was associated with the tornado occurrences was a squall line which formed at 1230 cst and moved eastward at 20–30 knots, decelerating and losing its identity after 2130 cst. Figure 8, the surface map for 1530 cst, April 3, shows this squall line which extended nearly north-south along a line from Green Bay, Wis., through Evansville, Ind., and Greenwood, Miss. There is

some radar evidence that this line consisted of three segments as this surface map indicates.

The two major areas of tornado activity on April 3 appeared to be associated with the higher-level wind patterns. Since the instability and low-level moisture were only slightly less on April 3 than on April 2, the severe activity near Lake Michigan again appears to have been associated with the jet maximum (fig. 6C) which moved from Texas to Kansas City, Mo., by 0900 cstr, April 3 (fig. 2). Likewise, even though the squall line extended from Lake Michigan to northern Mississippi, a second maximum area of severe activity (figs. 1 and 2) appears to have been associated with a low-latitude jet. This low-latitude jet of nearly 150 knots, without a well-defined maximum, had an elevation of about 40,000 feet. It was first detected at 0900 cstr, April 2 (fig. 6A) north of San Antonio, Tex., at a time when the polar jet maximum was 15,000 feet lower and located at El Paso, Tex. Even though it may have been influenced by the polar jet, the low-latitude jet, because of the height difference, does not appear to have been a branch or split of the polar jet. The intersection of the squall line and the region of decreasing cyclonic curvature west of this jet ridge line at 1530 cstr, April 3 (fig. 8) corresponds quite well to the outbreak of tornadoes in northern Louisiana and western Tennessee. Even though the low-latitude jet was both higher and weaker than the polar jet, it apparently was sufficiently important when combined with low-level moisture and instability to increase the severity of convective activity, resulting in tornadoes.

6. CONCLUSION

During the first three days of April 1956 the convective activity was fairly widespread and of varying intensity. Diurnal heating, plentiful moisture, and instability were undoubtedly all contributing factors to the convective

activity. However, it was mostly in the region of apparent upper tropospheric divergence patterns where the most severe activity occurred. The organization of the low-level features and their subsequent eastward movement were undoubtedly important both for understanding and anticipating the occurrence of tornadoes, but it is felt that the superposition of a strong upper-level divergence pattern over low-level moisture and instability was the single additional factor which contributed most to the occurrence of tornadoes.

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